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A personal computer based DSS for computer-family based selection

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THESIS

A PERSONAL COMPUTER BASED DSS

FOR

COMPUTER-FAMILY SELECTION

by

Donald A. Schmieley

March, 1991

Thesis Advisor: Moshe Zviran

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A Personal Computer Based DSS for Computer-Family Selection

by

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ABSTRACT

A decision support system to select a computer-family using an objective evaluation process is developed. A computer-family is defined as a group of computers from microcomputer to mainframe with compatible operating systems and software. Saaty's analytic hierarchy process is applied to the weighing and scoring stages of the computer-family selection methodology presented by Borovits and Zviran. The result is a decision support system incorporating an objective and comprehensive methodology for computer-family selection.

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I. INTRODUCTION

Changes in computer technology have brought changes in organizational computer systems. Many organizations are decentralizing their computer systems to meet new needs and take advantage of new technology. The speed with which computing needs change though, is remarkable and increases the uncertainty of computer selection processes. To compensate for this increased uncertainty, organizations with distributed or decentralized computer architecture tend to acquire families of computers which are compatible with one another and allow system growth. A computer family is defined as a group of computers, from the same manufacturer, which range from microcomputer to mainframe, are fully compatible with each other with respect to operating system and software, and are able to transfer applications from one family member to another without modification [Borovits and Zviran, 1987]. A computer system selection procedure which evaluates and chooses computer families, presents three distinct advantages over other computer selection procedures. First, it allows for the one-time evaluation and selection of a computer family. This procedure promotes uniformity throughout an organization and allows future configurations to be created from the existing computer family hardware. Secondly, it provides full compatibility between all components of the system. Compatibility between components promotes a savings of costs associated with integrating dissimilar components. Lastly, it allows the transfer of applications software without modifications. This functionality significantly reduces the duplication of development costs and allows for consistent information. Combined, these advantages promote a significant savings of costs and reduce the uncertainty associated with computer system selection. The only remaining problem is how to evaluate and select the best computer family for an organization. One procedure

which incorporates computer-families is a computer selection method which has been proposed by Borovits and Zviran [1987]. This method though, does not explain how a decision maker can evaluate all possible candidates and select the computer family that best meets the organization's needs. Zviran [1990] has elaborated on the method and proposed a solution to this problem by using Saaty's analytic hierarchy process to compare and evaluate the attributes of different computer families. This evaluation technique uses pairwise comparisons between different candidates on the same attribute. The resultant product is a normalized, weighted recommendation for a specific computer family based upon the organization's perceptions of the value of one family's abilities over another.

Although this proposed framework presents itself as a superior method for evaluation and selection, the process becomes lengthy and difficult to manage if the number of attributes or candidates is large. However, this difficulty can be resolved through the use of a decision support system. A decision support system (DSS) incorporating this proposed methodology would enable a decision maker to complete a comprehensive evaluation of all proposed candidates and choose the best system for the organization. Furthermore, a DSS would allow a decision maker to concentrate on the most important tasks, the evaluation and selection process, and not administrative tasks associated with handling of information. A decision support system would simplify the computer-family selection process.

The purpose of this thesis is to develop a decision support system incorporating Saaty's analytic hierarchy process into the proposed computer family selection procedure. In achieving this task, this study will address the issue of how to apply a given methodology to the selection of a computer family within the framework of a decision support system. A generalized approach to the development of this DSS involves

the determination of system requirements and design specifications for this system and the design of the dialog, data and model components.

A decision support system incorporating a comprehensive selection methodology will enable a decision maker to efficiently and effectively evaluate a variety of computer-families and arrive at a decision which yields the best choice for his or her organization.

II. COMPUTER SELECTION PROCEDURES

A. REVIEW OF COMPUTER SELECTION METHODOLOGIES

The process of selecting a computer system or a family of computers is normally a strategic decision for an organization. This decision is not easy and consequently many selection processes have evolved to help decision makers in carrying out this task. These processes may be simple or sophisticated, however, most contain the following stages to selection:

1. Analyzing the needs of the organization
2. Defining the requirements and attributes.
3. Issuing a request for proposal to various vendors.
4. Performing initial screening and evaluating and comparing the alternatives.
5. Selecting the best alternative and making the appropriate arrangements for acquiring the system.
6. Acceptance testing and acceptance. [Borvits and Zviran, 1987; Shoval and Lugasi, 1987]

The first three steps involve internal decisions and are preliminary to the selection process. The fourth and fifth steps though, are often merged to become: evaluate the alternatives and select the right candidate. Within this framework several distinct selection methods have appeared as shown in Figure 2.1.

Selection Method	Basic Reference
Weighted Scoring	Sharpe, 1969
Cost-Effectiveness Ratio	Joslin, 1977
Efficient-Frontier Model	Shoval and Lugasi, 1987
Lexigraphical Ordering	Ahituv and Neumann, 1986
Cost-Value	Timmreck, 1973
Requirement Costing	Borovits, 1984
Cost Benefit Ratio	Shoval and Lugasi, 1988
Present Value	Roenfelt and Fleck, 1976
Dynamic Approach	Ein-Dor, 1977
Multi-Attribute Utility Model	Shoval and Lugasi, 1987
Analytic Hierarchy Process	Seidmann and Arbel, 1984

Figure 2.1. Existing methods for computer selection [Zviran, 1990].

These methods vary greatly in what is examined and how the evaluation will be made. Some methods, for example, rely upon financial evaluation of both the requirements and the attributes. These methods require a determination of worth of the benefits as well as the cost of the system. Using various techniques, an overall cost or benefit is determined and the system with the highest overall benefit or lowest overall cost is selected. Other methods, such as weighted scoring, avoid financial analysis and concentrate on some measure of the systems' benefits or attributes. Within this type of analysis, a decision maker must assign weights or factors of importance for the different requirements. The candidate systems having the desired attributes are scored in a manner where the score contains a reflection of the requirements' weights. The resultant attribute scores are summed. Usually, the system with the highest total score is selected. Some methodologies take straight-forward approaches to this weighing and scoring technique and others are more complex and require a great deal of analysis.

1. Weighted Scoring

The most popular selection procedure is the weighted scoring or the additive weight process [Sharpe, 1969; Timmreck, 1973; Shoval and Lugasi, 1987]. With this method each attribute category is assigned a weight factor before evaluation of the alternatives. Then the individual alternative attributes are evaluated and assigned a score. The alternative's total score is a summation of all its attribute scores multiplied by their respective weight factor. The preferred alternative is the one with the highest total score. This method, although simple and easily understood, is not normative, which means it is not based on system of axioms expressing rational behavior of the evaluator. Additionally, it does not allow for any examination of consistency of the evaluator in the decision making process. [Timmreck, 1973; Shoval and Lugasi, 1987]

2. Cost-Effectiveness Ratio

The cost-effectiveness ratio is similar to the weighted scoring method, however, it also uses cost as a decision variable [Joslin, 1977; Borovits and Zviran, 1987]. The procedure is relatively simple, in that the same procedure as the weighted scoring is used, however, the sum of the scores are divided into the system's total cost. The resulting ratio or score is used to determine the system selection. The system with the lowest ratio is selected. [Joslin, 1977; Borovits and Zviran, 1987]

3. Efficient-Frontier Model

Another method used to compare competing systems is the efficient-frontier model [Shoval and Lugasi, 1987]. This method compares the attributes of two alternatives, determining which alternative's attribute dominates the other. By comparing all of one alternative's attributes against another, alternatives which are obviously inferior in most or all attributes can be eliminated from consideration. Selection is then made from the remaining alternatives. However, this method does not provide a decision maker with a clear choice, rather it has only acted as a screening process in which clearly inferior alternatives are eliminated. [Shoval and Lugasi, 1987]

4. Lexigraphical Ordering

Similar to the efficient-frontier model is lexigraphical ordering [Ahituv and Neumann, 1986; Shoval and Lugasi, 1987]. Lexigraphical ordering differs from the efficient-frontier model in that it requires ranking based on the alternatives' dominant attribute. This method is only successful though when a dominant attribute exists. [Ahituv and Neumann, 1986, Shoval and Lugasi, 1987]

5. Cost Value

Many methods are based on some financial evaluation method, usually the candidate's cost. Methods vary from purely cost evaluations

to some form of a cost benefit ratio. One purely cost method is cost value [Timmreck, 1973]. Cost value involves assigning monetary values to a set of desired attributes. Alternatives with these attributes have the assigned monetary value subtracted from their cost. The alternative with the lowest cost is then the desired candidate. [Timmreck, 1973]

6. Requirement Costing

Another cost method similar to cost value is requirement costing. Cost savings are assigned to the set of desired attributes. Alternatives without the desired attribute have the cost saving value added to their total cost. Those alternatives that have the attribute but a value higher than the estimated savings have the incremental value added to their total cost. The system with the lowest total cost is then selected. [Borovits, 1984; Davis, 1989]

7. Cost Benefit Ratio

The cost benefit ratio is another commonly used method of evaluating alternatives. Within this process both a numerical value representing the benefits of a particular alternative and the alternative's cost are used. The value representing the benefit is divided by the cost, and the alternative with the highest cost benefit ratio is selected. This method though relies on some other valuative methodology to assign the benefit values. However, this method does allow for a comparison of alternatives with dissimilar benefits and costs. [Shoval and Lugasi, 1988]

8. Present Value

Taking into consideration the total costs and savings of an alternative is the present value method [Roenfelt and Fleck, 1976]. Total costs are defined as the initial investment and recurring costs associated with operating the system [Roenfelt and Fleck, 1976]. Benefits are represented as estimated cost savings resulting from the system's use.

The present value of the estimated savings is subtracted from the present value of the system's cost. The alternative with the lowest net present value is selected. This method is widely used, but like all methods which assign a quantifiable value to benefits, it suffers from the lack of ability to validate the evaluations of the non-quantifiable benefits. [Roenfelt and Fleck, 1976]

9. Dynamic Approach

Another present value method is the dynamic approach, which involves projecting the organization's growth or future needs [Ein-Dor, 1977]. The projected growth is used to determine when system upgrade or replacement is required. The costs of the initial investment and projected improvements are evaluated through present value analysis. The alternative with the lowest present value is selected [Ein-Dor, 1977]. This analysis is sensitive to work load changes but assumes that interruptions due to upgrades or replacement are inconsequential. Additionally, this method only uses cost to discriminate between alternatives, therefore benefits or attributes not readily quantifiable by cost are not considered.

10. Multi-Attribute Utility Model

Keeney's multi-attribute utility model is one of the most sophisticated methods of evaluation [Shoval and Lugasi, 1987]. It requires both an evaluation of attributes and the calculation of their weights. It also takes risk and uncertaint ' nto consideration. The application of this model requires assumptions on both utility and preference independence. Utility independence requires that for a given attribute, its utility does not depend upon the remaining attributes. Preference independence assumes that for a comparison of a pair of attributes, the preference for one over the other does not depend upon any given level of the remaining attributes. Additionally, this model treats

the evaluation differently for evaluators with different attitudes towards risk. Evaluators indifferent to risk use the additive variant of this model. Evaluators not indifferent to risk use the multiplicative variation. In calculating the weights and constants for the attributes a form of the Von-Neuman-Morgenstern gambling technique is used [Shoval and Lugasi, 1987]. This gambling technique is used to determine the evaluator's indifference between two alternative's attribute utility. Upon determining all the weights and constants, the values for each alternative's attributes is summed, according to which method of risk evaluation is appropriate, and the alternative with the largest utility is chosen. This method is normative since it forces the decision maker to accept a set of axioms representing preferences and requires the examination of independence assumptions. It also considers risk and uncertainty, and allows for sensitivity analysis. However, this method is also more difficult to employ as it is difficult to understand. The point at which a decision maker is indifferent between alternatives is not always clear and the evaluators are often confused with the weighing technique. [Shoval and Lugasi, 1987]

11. Analytic Hierarchy Process

Saaty's analytic hierarchy process determines both an organization's needs and evaluates the candidates. Saaty's analytic hierarchy process provides a comprehensive selection procedure as it requires the pairwise comparison of all alternatives for every attribute or organizational requirement [Saaty, 1977; Seidman and Arbel, 1984; Zviran, 1990]. Within this method, all attributes are weighted using a hierarchical process involving pair-wise comparisons using a scale from one to nine, prior to evaluation of the alternatives. Values from the comparison fill up a comparison matrix which is n x n large, where n represents the number of attributes. The comparison matrix has only

positive values and satisfies the reciprocal property a(i,j) = 1/a(i,j). After the comparison matrix is filled its eigenvector corresponding to its largest eigenvalue is calculated and normalized. The values of this normalized eigenvector represent the relative scores for the various attributes. The scores are then multiplied by the next higher attribute weight to determine an absolute weight. This process continues until all attributes have been weighted. Moreover, this process produces a hierarchical tree of attributes as shown in Figure 2.2. Since all attributes are part of a hierarchical tree, the alternatives only need to be evaluated for the end nodes or leaves of the tree. The hierarchical nature of the tree incorporates the weighted values of all higher nodes. Following this procedure the alternatives are then compared for a given attribute using the same one to nine scale. The values from the comparison also fill up a comparison matrix which is solved in the same manner as before. This process continues until all alternatives has been evaluated for all end node or lowest level attributes. Once the all scores are solved, they are summed for the various alternatives using a process similar to the additive weight method. The alternatives are then ranked according to their summed scores and the preferred alternative is the one with the highest score. This process allows for consistency checks of the evaluator by considering whether the expression a(i,j) = a(i,k)*a(k,j) holds true for all triplets. A consistency ratio is then calculated for the maximum eigenvalue and is required to be less than 0.1 for acceptable consistency. However, this method does not consider risk or uncertainty. [Saaty, 1977; Seidman and Arbel, 1984; Shoval and Lugasi, 1987; Zviran, 1990]

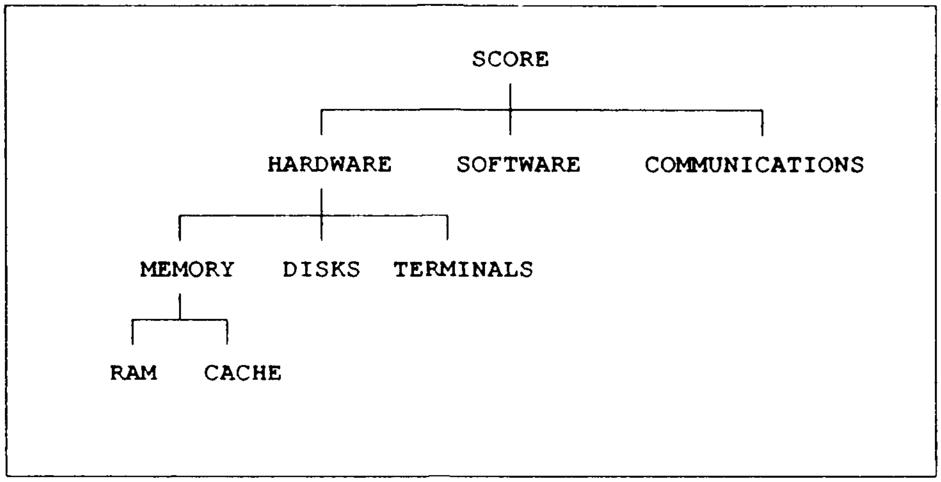

Figure 2.2. A hierarchy of attributes.

B. A COMPUTER-FAMILY SELECTION PROCEDURE

The previously discussed selection methodologies address the problem of selecting a single system or component, and do not address the problem of selecting a computer-family. Selecting a computer-family is significantly different from selecting a single system due to the diverse nature of computer families. Borovits and Zviran [1987] define a computer-family as:

> A family of computers of the same type, consisting of several models from the same manufacturer's product line, ranging from microcomputer to mainframe, with full compatibility in the operating system and the system's software, to enable transfer of application software from one family member to another without change.

To solve this problem, Borovits and Zviran [1987] proposed a methodology to select a computer-family. Their proposed methodology is divided into ten steps which will lead the decision maker to a preferred computer-family choice. A description of the methodology follows:

1. Identification of possible vendors whose product lines might satisfy the organization's needs.

2. Preliminary elimination of possible candidates which upon further investigation are clearly unsuited towards meeting the organization's needs.
3. Determination of mandatory requirements that candidate computer-families will be required to meet. Many of the requirements formulated in this step should be closely related to the definition of a computer-family.
4. Examination of vendor compliance with mandatory requirements. This step results in elimination of those candidates that have failed to meet the mandatory requirements described in step three.
5. Setting qualitative and quantitative criteria and respective weighing-scales. This step sets the importance weights to be applied for various attributes and benefits that will be evaluated. This step also considers real and perceived vendor performances when assigning the values for the weights.
6. Writing and issuing a request for proposals to selected vendors which meet the mandatory requirements.
7. Receiving, comparing and analyzing bids. Within this step the candidate computer-families are evaluated according to the previously described criteria. This step is probably the most crucial as many of the candidates may not exhibit a clear dominance over the others and there is no accepted guidelines for comparing computer-families. Borovits and Zviran though, have proposed a comparison process which breaks the families down into their component computer categories (ie. mainframe, minicomputer, microcomputer, etc.) and then compares the individual computers against one another. Their individual scores though, are brought back to the computer-family

classification and summed for the entire family according to the weights previously assigned using a process similar to the additive weight method.

8. Draw up a final list of vendors based on the final scores attained in the evaluation phase. Usually this list should contain three to four candidates most likely to succeed.

9. Perform benchmark tests of hardware and software to verify the system's characteristics prior to a final selection.

10. Final conclusions and selection of the best computer-family. After all testing is competed the decision maker will review and reconsider the relevant scores assigned to each computer-family and select the best candidate.

This methodology though, does not propose an objective evaluation mechanism to determine the weights and scores of the various attributes and alternatives. Without such a mechanism, the evaluations are subjectively determined, and thus, can reduce the overall effectiveness of the evaluation process and may be difficult to replicate [Seidman and AArbel, 1984; Davis, 1989]. Consequently, a more objective methodology is proposed by Zviran [1990] which incorporates Saaty's analytical hierarchy process into the computer-family selection methodology. The use of Saaty's analytic hierarchy process allows a more comprehensive and consistent evaluation of the attributes and alternatives. The analytic hierarchy process allows for the determination a comprehensive examination of many interacting factors, the prioritization of criteria and alternatives, and ultimately indicates a best alternative [Saaty, 1977; Zviran, 1990]. Moreover, this process allows for the computation of a consistency ratio which can be used to assess the consistency of the decision maker. This consistency ratio can be used to assess the

randomness of the decisions and as well as be compared to a standard. The standard should indicate an acceptable level of inconsistency which would be greater than perfect consistency but less than intolerable inconsistency [Saaty, 1977; Davis, 1989; Zviran, 1990]. If standard has been surpassed then the evaluations should be repeated until a satisfactory consistency is achieved [Saaty, 1977; Davis, 1989]. Thus, by using the analytic hierarchy process, a decision maker can prioritize and evaluate a large number of criteria and alternatives objectively.

Zviran's proposed methodology uses Saaty's analytic hierarchy process in the attribute weighing process (step 5) and in the evaluation of alternative computer families process (step 7). Zviran divides step five into seven sub-procedures which accomplish the selection and weighing of all evaluation criteria as follows:

5.1. Prioritize overall importance of qualitative and quantitative criteria.

5.2. Set qualitative criteria.

5.3. Select applicable computer categories.

5.4. Select sub-criteria for each criterion down to the lowest level.

5.5. Prioritize and weight all categories, criteria and sub-criteria.

5.6. Calculate the absolute weights for all criteria and sub-criteria.

Use of the analytic hierarchy process in the attribute weighing process allows the decision maker to determine the weighing criteria objectively. However, prior to this determination the decision maker must subjectively determine the relative importance between the quantitative and qualitative evaluations. Once this determination is made the decision maker can objectively determine the weights of both the qualitative and quantitative

criteria. Additionally, Zviran divided step seven into six sub-procedures to clarify the receiving, comparing and analyzing of the bids. These six steps are:

7.1. Assign each relevant model of computer from a proposed computer-family to a category.

7.2. Design comparison tables for each category.

7.3. Evaluate each computer model in accordance with criteria established in step five.

7.4. Calculate the absolute score for each criterion and each computer model.

7.5. Calculate the total score for each computer model.

7.6. Calculate the total score for each computer family.

These six evaluation steps allow a decision maker to methodically evaluate all models of proposed computer-families. Here the decision maker uses the analytic hierarchy process to compare the various candidates within a given category against one another. The hierarchical nature of the process allows for a determination of which computer family is the best selection. Moreover, use of the analytic hierarchy process in the evaluation stage allows for the objective evaluation of the alternatives. Combined with the steps of the Borovits and Zviran process, these additional sub-steps provide a more comprehensive evaluation process as shown in Figure 2.3. [Zviran, 1990]

Step 1. Identification of possible vendors and manufacturers.
Step 2. Determination of mandatory requirements.
Step 3. Examination of vendor's compliance with mandatory requirements.
Step 4. Primary elimination of irrelevant candidates.
Step 5. Setting qualitative and quantitative criteria and respective scales.
  5.1. Prioritize overall importance of qualitative and quantitative criteria.
  5.2. Set qualitative criteria.
  5.3. Select applicable computer categories.
  5.4. Select sub-criteria for each criterion down to the lowest level.
  5.5. Prioritize and weight all categories, criteria and sub-criteria.
  5.6. Calculate the absolute weights for all criteria and sub-criteria.
Step 6. Writing the RFP to be addressed to selected vendors.
Step 7. Receiving, comparing and analyzing bids.
  7.1. Assign each relevant model of computer from a proposed computer-family to a category.
  7.2. Design comparison tables for each category.
  7.3. Evaluate each computer model in accordance with criteria established in step five.
  7.4. Calculate the absolute score for each criterion and each computer model.
  7.5. Calculate the total score for each computer model.
  7.6. Calculate the total score for each computer family.
Step 8. Drawing up a final list of vendors.
Step 9. Performance of hardware and software benchmarks.
Step 10. Drawing final conclusions and selection of best computer-family

Figure 2.3. A comprehensive computer-family selection methodology: A workflow diagram. [Zviran, 1990]

One major drawback to using this methodology though, is the complexity of the process. The volume of information generated and the number of comparison matrices required to solve the analytic hierarchy process makes this procedure too cumbersome for realistic manual use. However, this process could be feasible through the use of a decision

support system. By incorporating this procedure into a computerized decision support system, a decision maker could very easily follow all the steps previously discussed. This system could be used to store, retrieve and manipulate the information required to allow a thorough and complete decision.

III. DECISION SUPPORT SYSTEM BASIC CHARACTERISTICS

A. REVIEW OF DSS FRAMEWORK COMPONENTS

A decision support system (DSS) is an interactive computer-based information system designed to support and enhance managerial decision making in semi-structured and unstructured situations. DSS's should support decision makers in all phases of the decision making process. DSS's allow decision makers to access organizational information, analyze it through some form of model representing an appropriate business or organizational function, and provide a recommended decision. Additionally, DSS's should allow a decision maker to perform some sort of sensitivity analysis through "what if" scenarios. [Sprague and Carlson, 1982; Awad, 1988; Turban, 1988]

These decision making processes can be rephrased into four phases: intelligence, design, choice, and implementation [Sprague and Carlson, 1982]. The intelligence phase represents those actions which include the gathering and processing of data into a useable format. The design phase lets the decision maker select models or design the model that will analyze the data. The choice phase performs the required manipulations and calculations as defined by the models and presents the decision maker with information to support a given choice or selection. However, DSS's do not make the decision, but rather provide a recommendation that can be accepted or rejected by the decision maker. The last phase, implementation, concerns the issues surrounding the execution of the decision. Another key issue is ease of use. DSS's should be easy to use. A system that is user friendly will be used, whereas a system that is difficult to use will not be used. The combination of all of these

features define decision support systems. [Sprague and Carlson, 1982; Awad, 1988; Davis, 1988; Turban, 1988]

Although definitions of DSS's vary, most descriptions contain the following three basic components: a database, a model base and a dialogue system. Figure 3.1 presents these components [Sprague and Carlson, 1982; Ariav and Ginzberg, 1985; Turban, 1988]. These three components have been broken down into sub-components by many authors, however, all agree on the functionality of the components.

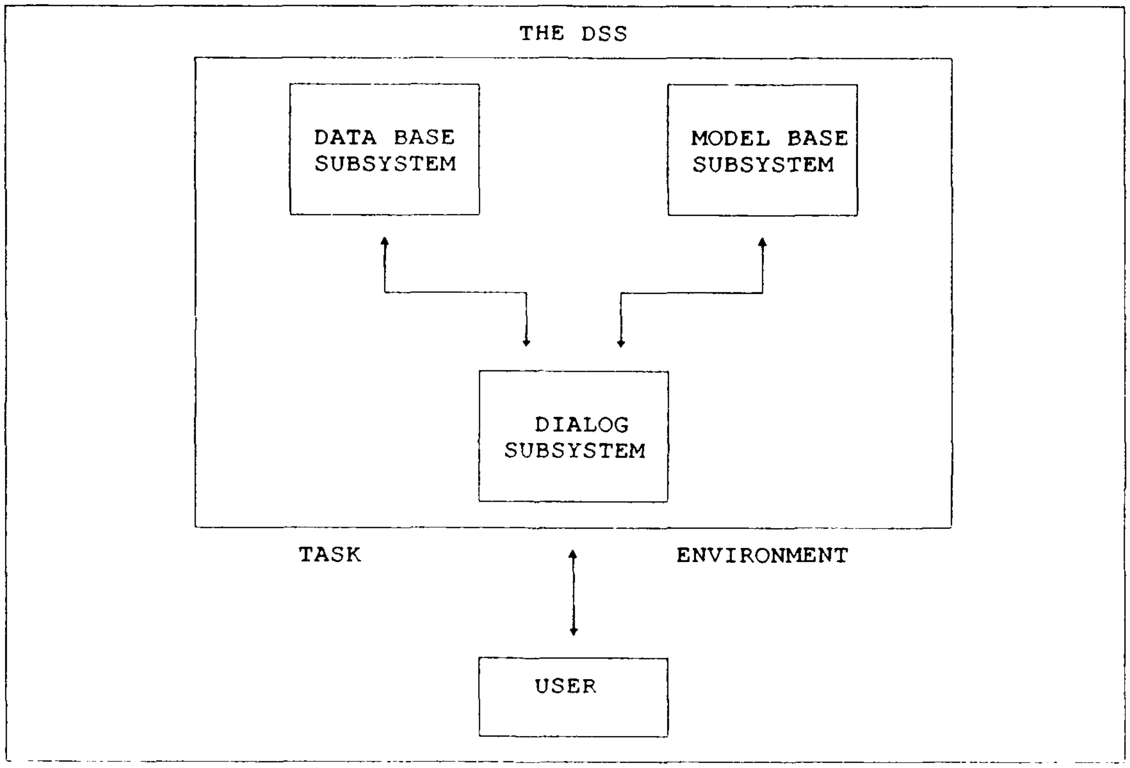

Figure 3.1. Components of a DSS. [Sprague and Carlson, 1982]

The first component is the database sub-system. This sub-system is composed of the following sub-components: a DSS database, database management system, data dictionary and query facility. Figure 3.2 illustrates the relationship between these sub-components.

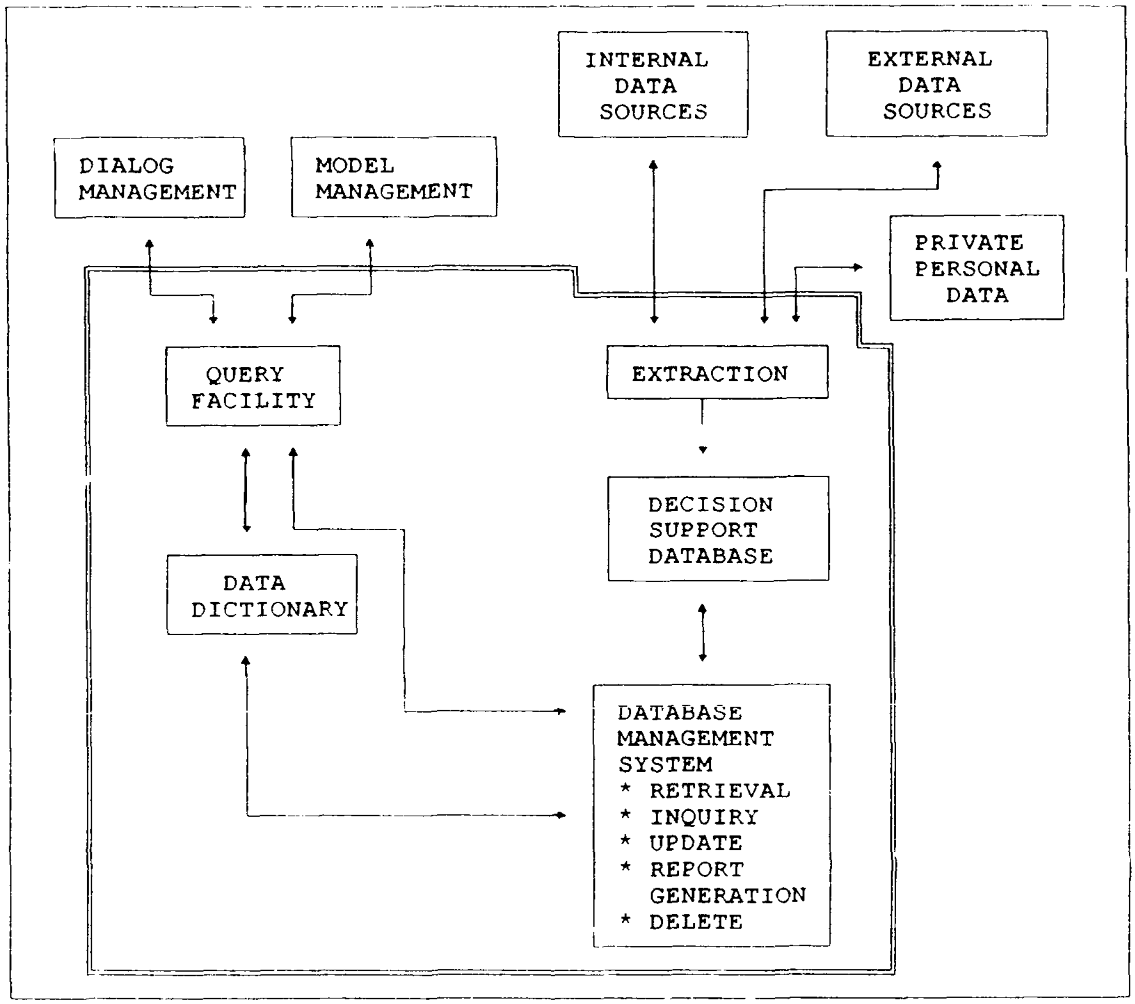

Figure 3.2. Data management system [Turban, 1988].

The DSS database is a collection of information that the DSS can access for problem solving analysis. This in: ' ,ation is often common to different applications and thus needs to be controlled by a database management system, which will allow access to the data but maintain its integrity. The database management system controls the storage and retrieval of the data and control of the database. The storage and retrieval functions are those functions which actually store and retrieve the data. The control function though, interacts between the user and the

other two functions ensuring that the user is an authorized user of both the system and the data. The query facility is the function which allows communication between the user and the database management system to describe what data is to be accessed. The data dictionary is a complete listing of all data in the database. Its function is to support the cataloging of all data to ensure the proper addition and deletion of data from the database, thus reducing data redundancy and promoting integrity. [Turban, 1988]

The model base is the DSS component that is used to analyze the data and provide a recommended solution. The model base is composed of four components: a model base, a model base management system, a model directory and model execution, integration and a command system [Turban, 1988]. The model base is presented in Figure 3.3. The model base is a collection of analytical models to be used by the decision maker in different analysis.

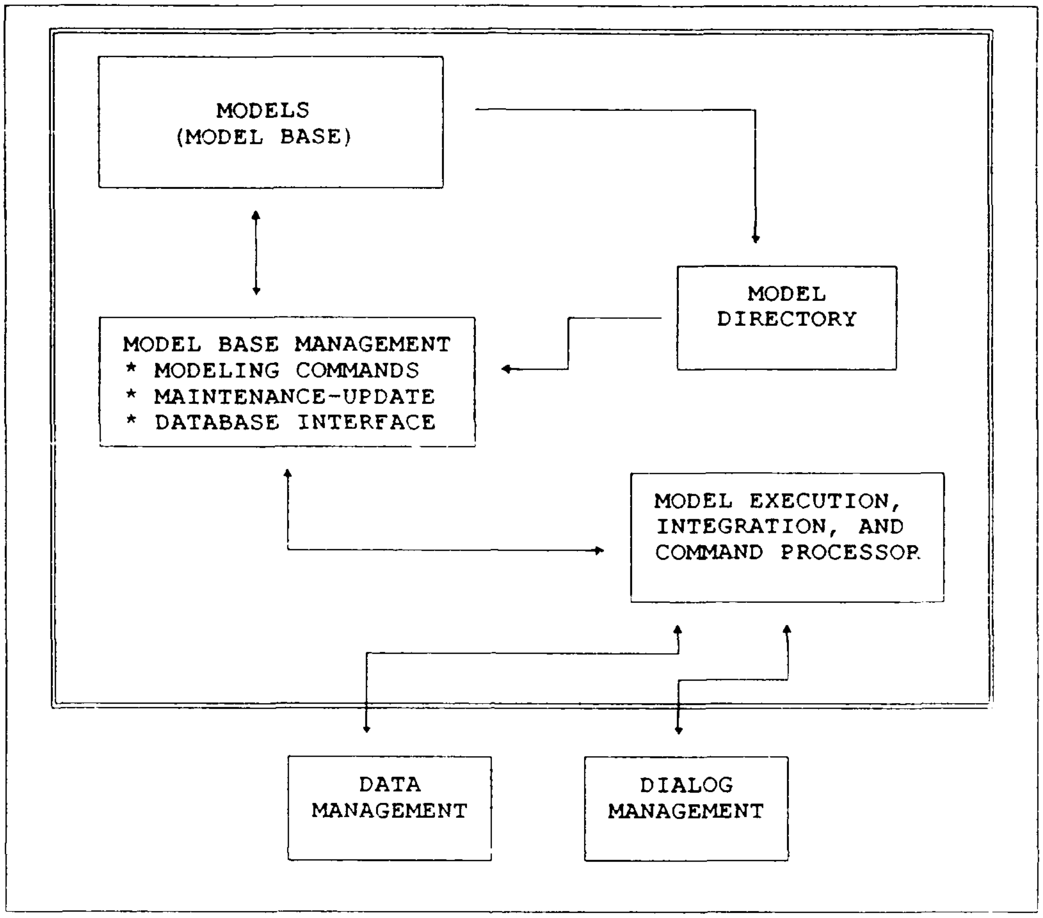

Figure 3.3. Model management system [Turban, 1988].

These models are representations of some business or organizational function that provides the results of some given set of actions or preferences. The model base management system is the component that controls the use of a specific model within an analysis. It allows the building of new models using existing models within the model base, or allows the addition or deletion of models to the model base. The model directory is similar to the data dictionary in that its function is to catalog all the models within the model base, including definitions and capabilities of the models. Lastly, the model execution, integration and command system controls the actual execution and integration of models,

and interprets the commands controlling execution and integration as they come from the user to the modeling subsystem. [Turban, 1988]

The last component of a DSS, the dialog sub-system, is the interface between the user and all other components of the DSS, and therefore is probably the most important component of the DSS. Figure 3.4 displays the relationship between the dialog sub-system and other DSS components. If the dialog system is difficult to use, the DSS will undoubtedly sit on the shelf unused, regardless of the accuracy of the analysis model or the database [Turban, 1988]. A dialog system must be user friendly and easy to use. It may be menu driven or a command language, but commands and terminology should be based on some definition of a user knowledge level to facilitate a user friendly atmosphere [Turban, 1988; Davis, 1988]. The dialog system incorporates both hardware and software aspects. A dialog system covers the methods by which the user communicates, whether by keyboard, light pen, mouse or some other hardware. The dialog system translates all communication from the user to the appropriate DSS component and vice versa. [Turban, 1988; Davis, 1988]

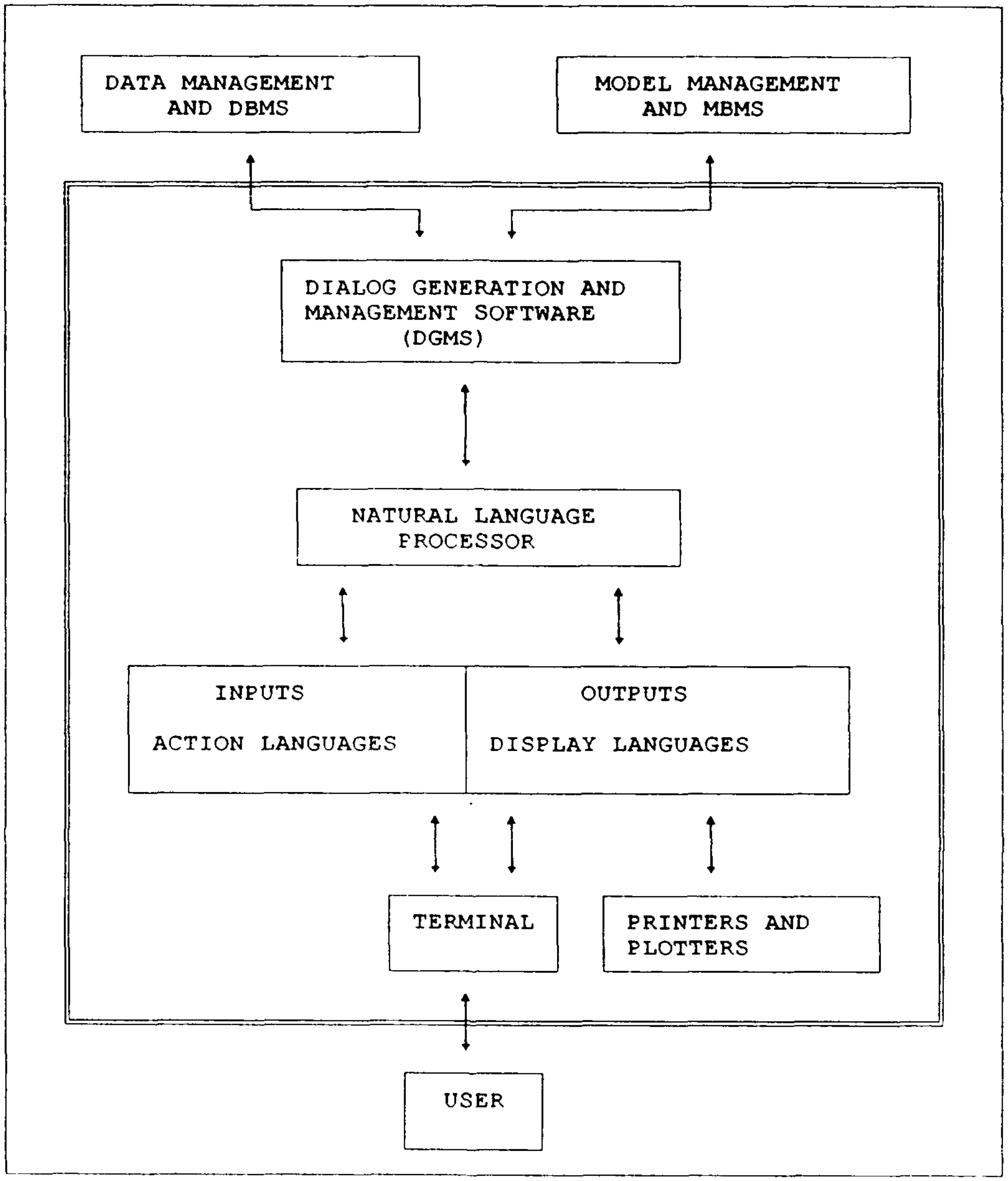

Figure 3.4. Dialog management system [Turban, 1988].

B. RATIONALE FOR DECISION SUPPORT SYSTEMS

As previously stated, DSS's are used to enhance managerial decision making in semi-structured and unstructured situations. DSS's are primarily used to help decision makers retrieve and analyze information in situations where the decision process is difficult or lengthy. Moreover, DSS's can significantly speed up the decision process in situations where a large volume of information must be analyzed using complex models. The ability to organize and store this information also significantly aids the decision process. By providing a decision maker with this type of support, a decision maker should be able to make a thorough and comprehensive analysis of the situation and ultimately make a better, more informed decision. [Sprague and Carlson, 1982; Awad, 1988; Turban, 1988]

The process of selecting a computer-family using the previously proposed methodology is a thorough but complex procedure. It requires a large volume of data to be analyzed using complex models. Manual accomplishment of this task would be very difficult and time consuming. Furthermore, it could result in an incomplete analysis and poor decision. However, this process could be significantly simplified for the decision maker if it was incorporated within a decision support system. A DSS would enable the decision maker to store, retrieve and analyze the information related to the decision process. A DSS could perform analysis using complex models in a much shorter time frame and less chance of error. Furthermore, a DSS would use a standard method of analysis, thus improving decision consistency while ensuring a fair and comprehensive analysis. Thus, the decision maker would be free from many of the administrative tasks involved in analyzing information. Even more importantly, a DSS would allow a decision maker to concentrate on the evaluation and decision making related to computer-family selection.

IV. DEVELOPMENT OF A DSS FOR COMPUTER-FAMILY SELECTION

A. DEVELOPMENT OF THE BASIC REQUIREMENTS

The requirements for developing a DSS for computer-family selection will define the DSS's goals, levels of technology, and required technical capabilities as a minimum. The DSS goals will describe what the DSS is supposed to do. The levels of technology will describe what will need to be built, and the required technical capabilities will describe the necessary technical functionality [Sprague and Carlson, 1982]. Therefore, the goal of this DSS development is to provide support to the decision maker for all phases of the computer-family selection process.

To provide support for all phases of the computer-family selection process, Zviran's proposed methodology needs to be redefined in the DSS framework components. Many of the selection procedures will involve several phases, but these steps can be further broken down. Within the proposed methodology, several steps comprise the intelligence phase. These steps are not contiguous, and occur throughout the process. Steps one and two primarily pertain to the intelligence phase. These first two steps refer to the collection of information regarding vendors and mandatory criteria. These two steps set the process in motion and must be completed before others can occur. Step three is part of the intelligence phase, as it requires gathering information ' each of the vendors with respect to the mandatory criteria. Step seven also pertains to the intelligence phase. Step seven involves the receipt and analysis of bids from the vendors. Although at this point use of the model is necessary, this step is mainly concerned with the gathering of information related to the preferences of the decision maker. Lastly, step nine can also be

considered part of the intelligence phase when it deals with the collection of information regarding benchmark test performances.

The next phase is the design phase. Step two has some elements of this phase as the determination of mandatory requirements also defines a model by which all vendors will first be evaluated. These criteria will determine which vendors continue through the process and which will be eliminated at this step. Step five also is part of the design phase, and is the crux of the model building within this DSS. Step five allows the decision maker to define and weight the evaluation criteria using a generic, predefined model contained in the model base. This model encompasses the selection of evaluation criteria and the weighing of these criteria using Saaty's analytic hierarchy procedure. The last step in this phase is step nine. Step nine involves the determination and performance of benchmark tests. These tests, although not performed by the DSS, help to define the decision making process.

The next step is the choice phase. This phase provides the decision maker with information supporting a choice or decision. The first step in the methodology in this phase is step four. Step four provides information regarding the compliance of the vendors with the mandatory criteria. This information allows the decision maker to determine which vendors will be eliminated from the selection process. Step eight is the next step in the methodology within the choice phase. Step eight provides information to the decision maker to allow a determination of the final list of vendors. The last step in this phase is the last step in the process, step ten. Step ten culminates in the decision maker's ability to selection a given computer-family for his organization, and represents the final goal of the DSS.

The implementation phase does not directly support the final computer-family selection, but does support the overall process, particularly some

of the intermediate decisions. Step six is part of the implementation phase as it provides support for the writing of the request for proposal based on the determination of vendor compliance with mandatory criteria. The determination of vendor compliance is an intermediate, but necessary decision that must be made and implemented.

In summary, the proposed computer-family methodology can be divided into the separate decision making components. These components can be arranged in an orderly fashion to facilitate the use of a decision support system to aid the decision maker, and thereby make the process more objective and easy.

B. DISCUSSION OF THE DESIGN

The next step in the development of a DSS is the design stage. Within this stage several issues must be decided. Some of these issues are related to the future plans of the DSS, as well as the type and resources of the organization or individuals developing the DSS. Other issues are more directly related to the DSS itself. Features such as ease of use, number and type of models to be included, and data structure must be determined. These features are incorporated into the dialog, model base and data base sub-systems.

The model base for this project is both basic and complicated. This DSS needs only a couple of models which the user can tailor to his own needs. The first model the user would encounter is the elimination of irrelevant vendors based on the mandatory criteria. This model is very basic as it only requires a comparison of vendor capabilities with the mandatory requirements. Manually this model would be similar to a matrix or chart which would show both vendor and mandatory requirements, and the user would indicate which requirements where met. To eliminate the irrelevant vendors, the user would only have to observe which vendors did

not meet all the requirements. However, the model which represents Saaty's analytic hierarchy process is fairly complex. This model represents the major model component of this DSS and requires complex calculations which are best suited for a computerized system. This model would be used first in the determination of the evaluation criteria and weights. Later this model would again be used to evaluate the bids, using the previously determined weights.

The database in this DSS is important but also basic. Most of the information used in this selection process is supplied by the user, and therefore the biggest job of the database is simply to perform the basic functions of storage, retrieval and update. Since most of the information is simple and related to a particular vendor, a record format lends itself to this project. Records can be created easily and add a specified structure which is convenient to manipulate. Additionally separate records can be used to maintain the data for individual steps of the process to facilitate audit trails. This separation of data and use of several records adds redundancy and inefficiency. However, for the purpose of being able to recreate the separate steps of the process at a later time this inefficiency is necessary.

The dialog component of this DSS is very important. This DSS is designed for a relatively high level decision maker since computer-family selection is a strategic decision. Furthermore, this process would probably be used only once by a specific organization. Therefore, it is imperative that this DSS be easy to use and user friendly since users will not want to invest a lot of time learning the system. Additionally, since this DSS uses a specific methodology and complex models, the dialog sub-system needs to be able to lead the user through the process. By using a simple hierarchical menu, the steps of the process can be controlled while easily leading the user to the desired functions. Furthermore, a

menu system facilitates a speedy learning curve and only requires system installation prior to use. From the main menu the user immediately could begin the selection process, provided the required information is available. Moreover, the menu system would control the model and database sub-systems. Since many of the steps of this process are sequential, the menu system would call the appropriate model and data as necessary. After the desired function has been performed, control would be returned to the menu system. Therefore, all steps of the process begin and end with the menu system.

V. SELECT--A DSS FOR COMPUTER-FAMILY SELECTION

A. CLASSIFICATION

SELECT is a DSS that has been designed and developed in order to facilitate the use of Saaty's analytic hierarchy process in a computer family selection procedure. SELECT is a personal support ad-hoc analysis information system, primarily designed for a single user. It can, however, be used by a group of users performing the selection of a computer family through a facilitator. The decisions involved are normally non-recurring but of a strategic nature, and therefore qualify for an ad hoc DSS. SELECT aids a decision maker by analyzing the information that the user enters into the system. This analysis is accomplished through the use of customized models and databases. Part of the functionality of a decision support system is to be able to be customized for individual users. SELECT can easily be customized for a variety of organizations or users as the user must indicate certain preferences and supply the data necessary to allow analysis. Each organization or decision maker using SELECT must enter their own information. This information includes vendor data, mandatory criteria and benchmark tests. SELECT stores this information in small separate databases, which also provides a useful audit trail for later analysis. Additionally, the organization or decision maker must customize the generic models which are used to analyze the decision variables. These decision variables are in the form of evaluation criteria. The user hierarchically builds a set of evaluation criteria which are weighted using Saaty's analytic hierarchy process. This hierarchical list provides the model representing the decision maker's preferences with regard to the evaluation criteria. Later, this model will be used to evaluate each of

the bids being considered. From this analysis, scores will be generated and allow the decision maker to reach a decision regarding selection of a computer family.

B. USING SELECT

1. Basic requirements

To use SELECT, a user needs an IBM or compatible personal computer with a 5-1/4 inch floppy drive and a hard drive with at least 1.2 megabytes of available storage. The computer must use MS-DOS or compatible operating system which can run BASIC.

2. Getting started

Before using SELECT, the system has to be installed on a computer's hard drive. The installation of SELECT requires copying all of the files on the floppy disk to a designated directory on your hard drive. To start the system, simply type SELECT and press "enter".

C. USING SELECT FOR COMPUTER-FAMILY SELECTION

SELECT is an easy to use, menu driven system. The first screen displayed after initiating the system is the opening screen. From the opening screen a user need only follow the displayed directions to get to the main menu. From the main menu a user can access any of the major steps in the computer-family selection process. Figure 5.1 displays the main menu. All main menu options lead to sub-menus which allow further selection and lead to the desired functions. All menus and sub-menus are operated by the cursor keys and return key. When the desired function is obtained the user will be prompted to supply the required information by instructions normally located at the bottom of the screen. The prompts are straight-forward and are combined with either a question and answer or

query by form format. The main menu basically follows the ten-step methodology as previously described.

```
MAIN MENU

GENERAL INFORMATION
VENDOR LIST PREPARATION
ENTER MANDATORY CRITERIA LIST
ENTER EVALUATION CRITERIA AND WEIGHTS
ENTER REQUEST FOR PROPOSALS LIST
ANALYZE BIDS
DETERMINE FINAL VENDOR LIST
ENTER BENCHMARK TEST LIST
DETERMINE FINAL RESULTS
DISPLAY PROCESS HISTORY
EXIT PROGRAM

USE ARROW KEYS (↑↓) TO SELECT YOUR CHOICE
PRESS ENTER (↵) TO OPERATE
```

Figure 5.1. Main menu.

The first entry on the main menu is general information. General information gives the user a brief description of SELECT and the computer-family selection methodology. This option returns the user to the main menu upon completion.

The first step in selecting a computer-family is to create an initial vendor list. Selecting vendor list preparation from the main menu takes the user to the vendor menu as shown in Figure 5.2. From the vendor menu, the user can create an initial vendor list by selecting initiate vendor list. Figure 5.3 presents the form that the user will be lead through to enter the vendor data.

VENDOR MENU

INITIATE VENDOR LIST
UPDATE VENDOR LIST
ADD VENDOR TO LIST
DELETE VENDOR FROM LIST
DISPLAY VENDOR LIST
PRINT VENDOR LIST
RETURN TO MAIN MENU

USE ARROW KEYS (↑↓) TO SELECT YOUR CHOICE
PRESS ENTER (↵) TO OPERATE

Figure 5.2. Vendor menu.

VENDOR INFORMATION

COMPANY ____________________
ADDRESS ________________________________
CITY ______________________ STATE __
ZIP CODE ___________
PHONE NUMBER ______________
POINT OF CONTACT ______________________
COMPUTER FAMILY NAME __________________
SENT RFP (Y/N) _ RECEIVED BID (Y/N) _

PRESS <RTN> TO CONTINUE TO NEXT ENTRY
PRESS <ALT-R> TO RETURN TO PREVIOUS MENU

Figure 5.3. Vendor information form.

If the user does not have all the information indicated on the form, he or she can skip the block and update the it at a later time. Other options allow the user to add and delete vendors from the list as necessary. It should be noted though, that at this point in the selection process, the user should only be trying to identify potential vendors. Inclusion of a vendor on this initial list in no way signifies any ability of the vendor to satisfy the organization's requirements.

The next step in the selection process is to determine mandatory criteria. All vendors must comply with the mandatory criteria to continue in the process. From the main menu the user should select enter mandatory criteria. This option displays the mandatory criteria menu as presented in Figure 5.4.

```
MANDATORY CRITERIA MENU

ENTER NEW CRITERIA LIST
ADD CRITERIA TO EXISTING LIST
DELETE CRITERIA FROM EXISTING LIST
EXAMINE VENDOR COMPLIANCE
ELIMINATE IRRELEVANT CANDIDATES
DISPLAY CRITERIA LIST
DISPLAY RESULTANT VENDOR LIST
PRINT CRITERIA LIST
PRINT RESULTANT VENDOR LIST
RETURN TO MAIN MENU

USE ARROW KEYS (↑↓) TO SELECT YOUR CHOICE
PRESS ENTER (↵) TO OPERATE
```

Figure 5.4. Mandatory criteria menu.

From this sub-menu the user would select enter new criteria list. This option presents the user with a blank numbered list, which the user can fill out. Each entry on the list constitutes one mandatory criteria. After creating the list, it can be edited as necessary.

To evaluate the vendors' compliance with the mandatory criteria the user would select examine vendor compliance. This option presents the user with the list of vendors by vendor name only. First the user selects the vendor they wish to evaluate. Then SELECT presents the user with the list of mandatory criteria. To indicate which mandatory criteria the vendor complies with, the user highlights the criteria with the cursor keys and presses "enter". This information is stored in a database. When all vendors have been checked for mandatory criteria compliance, the next

step is to eliminate the irrelevant candidates. When selected, the option eliminate irrelevant candidates displays all the vendors by name and shows which vendors comply with all mandatory criteria. Figure 5.5 presents an example of the eliminate irrelevant candidates screen.

```
VENDORS WHICH MEET ALL MANDATORY CRITERIA
       ARE MARKED WITH AN ASTERISK

                AMDAHL CORP
             *  BULL HN
             *  DIGITAL EQUIPT
                IBM
             *  TANDEM
                UNISYS

 DO YOU WISH TO INCLUDE VENDORS WHICH DO
 NOT MEET ALL MANDATORY CRITERIA (Y/N)?
 VENDORS NOT SELECTED AT THIS STAGE WILL BE
 ELIMINATED FROM FURTHER CONSIDERATION.
 SELECTED VENDORS WILL BE AUTOMATICALLY
 PLACED ON THE RFP MAILING LIST.
```

Figure 5.5. Eliminate irrelevant candidates screen.

The user is prompted to decide whether vendors which do not meet all the mandatory criteria will continue in the process. If the vendor responds negatively, the vendors meeting all mandatory criteria will be stored in another database. These vendors will continue in the computer-family selection process. However, if the user answers yes to the prompt, the user will be able to include vendors not meeting the mandatory criteria in the database, although this defeats the purpose of mandatory criteria compliance.

The next step in the selection process is to create an evaluation criteria list. From the main menu the user would select the enter evaluation criteria and weights option. This selection calls a sub-menu from which the user can begin creating the model that will later be used to evaluate vendor bids. The first option on this sub-menu determines the weight to be given the qualitative and quantitative criteria. The range

of values is based upon a zero to one hundred percent scale, with the combined weights equalling one hundred percent. The decision maker enters the weight of the qualitative criteria and the resulting weight for the quantitative criteria is calculated and displayed. The user can then change the weights or store them. The other two options from this sub-menu call either the qualitative or quantitative criteria sub-menus. From these sub-menus the user can create and edit the evaluation criteria model from suggested criteria lists. These lists are hierarchically arranged and allow the user to enter his or her own criteria if it is not listed. The qualitative criteria lists are two levels deep, while the quantitative criteria lists can go as deep as five levels. After the user has created the criteria lists, he or she must weigh them. Weighing the criteria is necessary to indicate the relative importance of the various criteria. All criteria within a given level and category are compared to each other using Saaty's analytic hierarchy process. In this procedure all criteria are compared in a pairwise fashion and given weights describing the relative importance of one criteria with respect to the other. This weighing creates the model by which all bids will be evaluated. Figure 5.6 shows an example of the weighing process.

```
PLEASE ENTER THE RELATIVE IMPORTANCE OF CRITERION
A:   100 VENDOR SUPPORT
               ON CRITERION
B:   200 VENDOR REPUTATION

 LEVEL        DESCRIPTION
   1          EQUAL IMPORTANCE
   3          WEAK IMPORTANCE
   5          STRONG IMPORTANCE
   7          DEMONSTRATED IMPORTANCE
   9          ABSOLUTE IMPORTANCE
 2,4,6,8 ARE INTERMEDIATE VALUES BETWEEN LEVELS
 USE NEGATIVE VALUES TO INDICATE RECIPROCALS (B>A)
```

Figure 5.6. Criteria weighing screen.

When all the criteria for a given level have been compared, the matrix is solved for its real roots, which are translated into weights for the individual criteria. Absolute weighing values for the criteria are calculated by multiplying the weights of hierarchically superior criteria with the weights of their respective sub-criteria. The user can view both the relative and absolute weights for each of the criteria as shown in Figure 5.7. The absolute weights are then stored and used to determine the absolute weights of subsequent sub-criteria. When all criteria have been compared and weighed the evaluation model customization is complete. The resulting model will be used to evaluate the vendors' bids.

QUALITATIVE CRITERIA	RELATIVE WEIGHTS
100 VENDOR SUPPORT	0.547
200 VENDOR REPUTATION	0.263
300 SPREAD OF USE	0.190

PRESS <PAGE UP> TO VIEW ABSOLUTE WEIGHTS
PRESS <PAGE DOWN> TO VIEW RELATIVE WEIGHTS
PRESS <ALT-E> TO EDIT CRITERIA WEIGHTS
PRESS <ALT-C> TO CONTINUE

Figure 5.7. Criteria weights table.

The next step in the computer-family selection process is to send requests for proposals (RFP) to vendors which met all the mandatory criteria. From the main menu the user can choose the enter requests for proposals list option, which displays the request for proposals sub-menu. From this sub-menu the user can display all the vendors which met the mandatory criteria and now make up the RFP mailing list. Other options include updating vendor information, and displaying or printing the RFP mailing list or the qualitative or quantitative criteria.

After sending the requests for proposals, the next step in the computer-family selection process is to evaluate the vendors' bids. To complete this step however, the user must wait until all bids have been

received and studied. When the user is ready to evaluate the bids, he or she can select analyze bids from the main menu. This option displays the bid analysis menu shown in Figure 5.8. The first entry on this menu, enter computer family information, is the next step of the process. This option prompts the user to indicate whether each vendor on the RFP mailing returned a bid. If the vendor returned a bid, the user is prompted to indicate how many separate computer families were included on the bid, and the computer family names. Vendors which did not return a bid are eliminated from further analysis. All of the information is stored in another small database.

After entering all the necessary bid information, the next step is to evaluate the bids using the previously created model. At this point the user can select either evaluate qualitative criteria or evaluate quantitative criteria.

```
                BID ANALYSIS MENU

     ENTER COMPUTER FAMILY BID INFORMATION
     EVALUATE QUALITATIVE CRITERIA
     EVALUATE QUANTITATIVE CRITERIA
     DISPLAY SCORES
     PRINT SCORES
     RETURN TO MAIN MENU

   USE ARROW KEYS (↑↓) TO SELECT YOUR CHOICE
   PRESS ENTER (↵) TO OPERATE
```

Figure 5.8. Bids analysis menu.

Both must be eventually selected, but it does not matter which is completed first. When all bids have been evaluated for both qualitative and quantitative criteria the user can display the resultant scores. The display scores option totals scores for each computer-family member and the qualitative score for the family. The qualitative score for the

family is displayed as well as the different computer categories within the family. The user then selects the computer category for which the members names and scores will be displayed. From this option the user can also display the members of a given computer family which scored the highest within that family. Accordingly these members are the only ones from that family which will continue in the selection process. Figure 5.9 presents an example of the computer family members by category which received the highest scores within the family.

```
            RECOMMENDED COMPUTER FAMILY MEMBERS
FAMILY      CATEGORY          MEMBER            SCORE

BULL        MAINFRAME         VAX 9000 420       0.161

DEC VAX     MINICOMPUTER      VAX 6000 210       0.036

TANDEM      MICROCOMPUTER     DECSTATION 325c    0.013


            QUALITATIVE SCORE                    0.099
            TOTAL FAMILY SCORE                   0.309

  SCORES MARKED WITH AN '*' ARE LESS THAN .001

    PRESS ENTER (↵) TO OPERATE
    PRESS <ALT-R> TO RETURN TO PREVIOUS MENU
    PRESS <ALT-C> TO CONTINUE
```

Figure 5.9. Computer-family members screen.

Following evaluation of the bids, the next step is to determine the final vendor list. The final vendor list consists of those vendors which will continue to be considered for selection. These vendors are selected for continuation based upon the scores they received during the analysis phase and usually are the top three or four scoring candidates. These vendors make up the final vendor list. To indicate which vendors are on the final vendor list the user would select determine final vendor list from the main menu. Figure 5.10 displays the final vendor menu. From the final vendor menu the user would select determine final vendor list.

```
FINAL VENDOR MENU

DETERMINE FINAL VENDOR LIST
DISPLAY FINAL VENDOR LIST
PRINT FINAL VENDOR LIST
RETURN TO MAIN MENU

USE ARROW KEYS (↑↓) TO SELECT YOUR CHOICE
PRESS ENTER (↵) TO OPERATE
```

Figure 5.10. Final vendor menu.

The determine final vendor list option displays all the vendors and their respective scores. These scores are sums of the highest scoring members of each category within the computer-family and the family qualitative score. The user then selects the computer-families that he or she wishes to further evaluate. Figure 5.11 gives an example of the display used to determine the final vendor list. The selected computer-families and their respective vendors become the final vendor list from which the final selection will be made.

FINAL COMPUTER FAMILY RANKING LIST

PLEASE SELECT THOSE COMPUTER FAMILIES THAT WILL BE GIVEN BENCHMARK TESTS. FAMILIES GIVEN BENCHMARK TESTS WILL BE MARKED WITH AN ASTERISK.

VENDOR	FAMILY	FINAL SCORE
BULL HN	BULL	0.227
DIGITAL EQUIPT	DEC VAX	0.309
TANDEM	TANDEM	0.146

USE ARROW KEYS (↑↓) TO SELECT YOUR CHOICE
PRESS ENTER (↵) TO ENTER RANKING VALUES
PRESS <ALT-R> TO RETURN TO PREVIOUS MENU
PRESS <ALT-C> TO RETURN TO MAIN MENU
PRESS <ALT-E> TO ERASE LAST ENTRY

Figure 5.11. Determine final vendor list screen.

After determining the final vendor list, the selected computer-families will be given benchmarks tests to complete the evaluation process. From the main menu the user selects enter benchmark test list. This option displays the benchmark test menu. From this menu the user can create and edit a benchmark test list. This list contains all the benchmark tests that will be performed on the remaining candidates. The feature provides a place for the user to record what tests were performed and also lets him or her record the results. By selecting evaluate benchmark performance from the benchmark test menu, the user will be able to record the results of the benchmark tests for each of the remaining computer families. From these results and the previous evaluations the decision maker can rank order the vendors and their computer families. To accomplish this final step the user can select determine final results from the main menu. The final results menu will be displayed and is very similar in functionality to the determine final vendor list menu. From

this menu the user selects determine final results. This option will display all the vendors and allow the user to indicate their ranking as shown in Figure 5.12.

COMPUTER FAMILY RANKING LIST

PLEASE RANK THE COMPUTER FAMILIES IN ORDER OF PREFERENCE

VENDOR	FAMILY	RANK
BULL HN	BULL	2
DIGITAL EQUIPT	DEC VAX	1
TANDEM	TANDEM	3

USE ARROW KEYS (↑↓) TO SELECT YOUR CHOICE
PRESS ENTER (↵) TO ENTER RANKING VALUES
PRESS <ALT-R> TO RETURN TO PREVIOUS MENU

Figure 5.12. Determine final results screen.

The vendor with the number one ranking signifies the final selection. This vendor will be selected to fulfill the organization's needs. Although unnecessary if all goes well, the ranking prevents the decision maker from having to repeat the evaluations if the number one vendor is unable to honor the bid or satisfy the organization in some manner.

The last entry on the main menu is not part of the computer-family selection process but is necessary to support the process and the organization. The last entry before exit program is display process history. This option presents the display menu which lists major decision points or information in the process. From this menu the user is able to select some portion of the process that has been recorded and retrieve it. Figure 5.13 presents the display menu. The user can choose whether the information is to be displayed on the screen, printed, or written to some other file as shown in Figure 5.14. This added functionality allows the decision maker and organization an audit trail of the entire process.

```
DISPLAY MENU

DISPLAY VENDOR LIST
DISPLAY MANDATORY CRITERIA
DISPLAY VENDOR COMPLIANCE RESULTS
DISPLAY REQUEST FOR PROPOSALS LIST
DISPLAY EVALUATION CRITERIA LIST
DISPLAY VENDOR SCORES
DISPLAY FINAL VENDOR RANKINGS
DISPLAY BENCHMARK LIST
DISPLAY FINAL RESULTS
RETURN TO MAIN MENU

USE ARROW KEYS (↑↓) TO SELECT YOUR CHOICE
PRESS ENTER (↵) TO OPERATE
```

Figure 5.13. Display menu.

```
DEVICE MENU

DISPLAY FILE
PRINT FILE
WRITE FILE TO DISK
RETURN TO DISPLAY MENU
RETURN TO MAIN MENU

USE ARROW KEYS (↑↓) TO SELECT YOUR CHOICE
PRESS ENTER (↵) TO OPERATE
```

Figure 5.14. Device menu.

VI. CONCLUSION

The process of selecting computer-families is complex. A formal methodology has been developed to aid decision makers in selecting computer-families. This process significantly reduces the uncertainty the decision maker faces in choosing the right system for an organization. Moreover, it yields a normalized, weighted choice which represents the best selection for the organization. However, this selection process requires a decision maker to collect and analyze a large amount of information. The administrative tasks associated with such a volume of information significantly increases the amount of time a decision maker must spend on the evaluation and selection process. Through the use of a decision support system incorporating the computer-family selection procedure though, a decision maker can efficiently and effectively evaluate this information and choose a computer family which is best for the organization. A decision support system would eliminate much of the time consuming administrative tasks associated with handling the information and allow the decision maker to concentrate on the evaluation and selection process.

A recommendation for future studies would be to enhance this DSS into a group decision support system, since decisions of this type would most likely not be made by a single individual. Rather, a group of individuals from an organization would be selected to evaluate the organization's needs, and then analyze and select a computer family to meet those needs.

By using the DSS developed in this thesis, the computer-family selection procedure using Saaty's analytic hierarchy process has been made usable for all decision makers attempting to select computer-families. This DSS is both user friendly and easy to use, and does not require any in-depth training. Moreover, it simplifies a comprehensive but complex

procedure thus allowing decision makers the luxury of easy, yet thorough evaluations. Through the use of this decision support system, it is now possible for decision makers to quickly apply the computer-family selection process in resolving their own organizational needs.

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